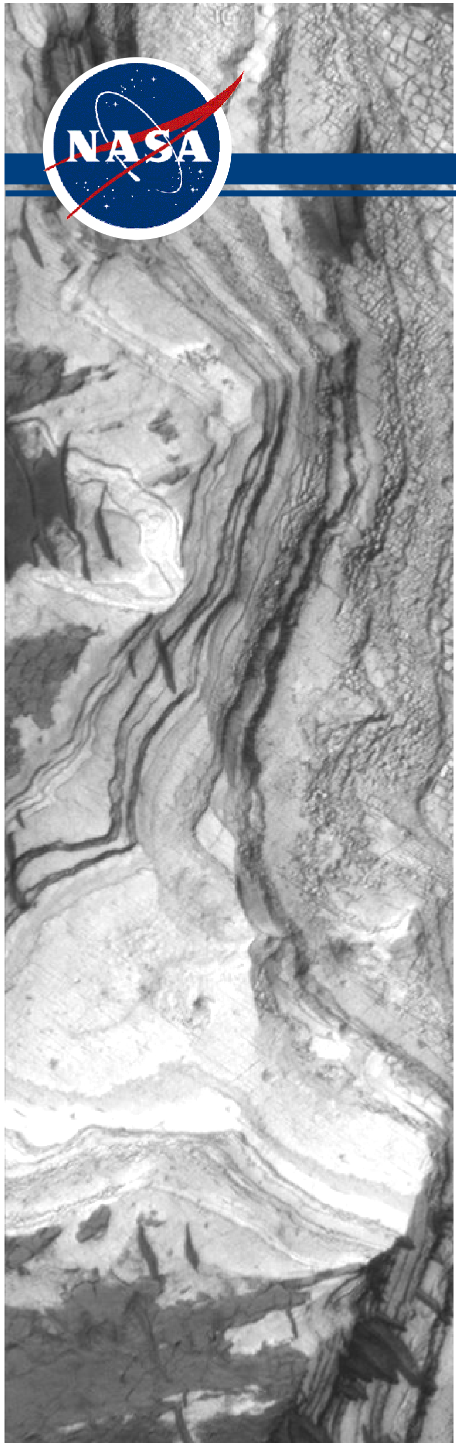
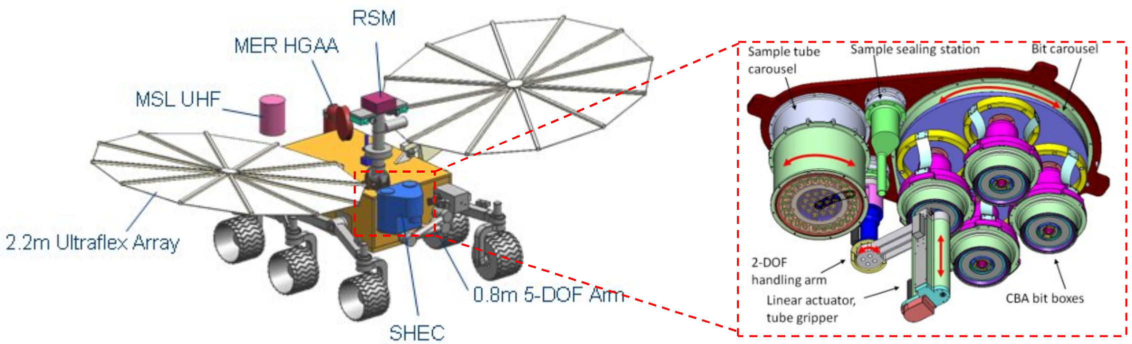


A Sample Handling, Encapsulation, and Containerization Subsystem Concept for Mars Sample Caching Missions



7th International Planetary Probe Workshop
Barcelona, Spain

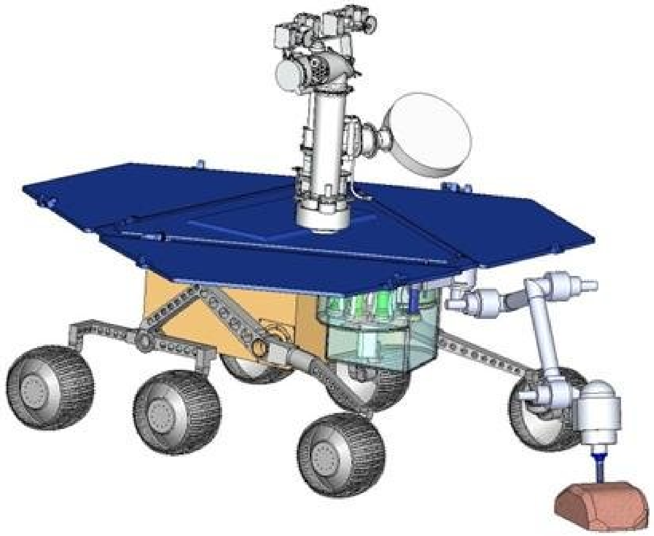
Paulo Younse, Curtis Collins, Paul Backes
Jet Propulsion Laboratory
California Institute of Technology

17 June 2010

The subject matter in this paper is pre-decisional, and for discussion purposes only.

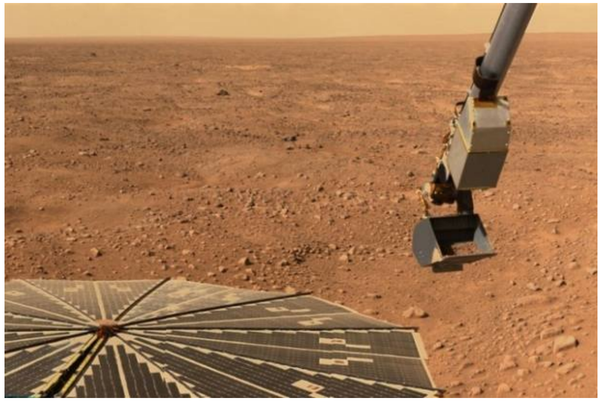
Outline

- **Sample Caching for Mars Sample Return**
- **Integrated Mars Sample Acquisition & Handling (IMSAH)**
- **Previous Mars Caching Concepts**
- **Sample Handling, Encapsulation & Containerization System (SHEC)**
- **SHEC Animation**
- **SHEC Prototype**
- **Conclusion**



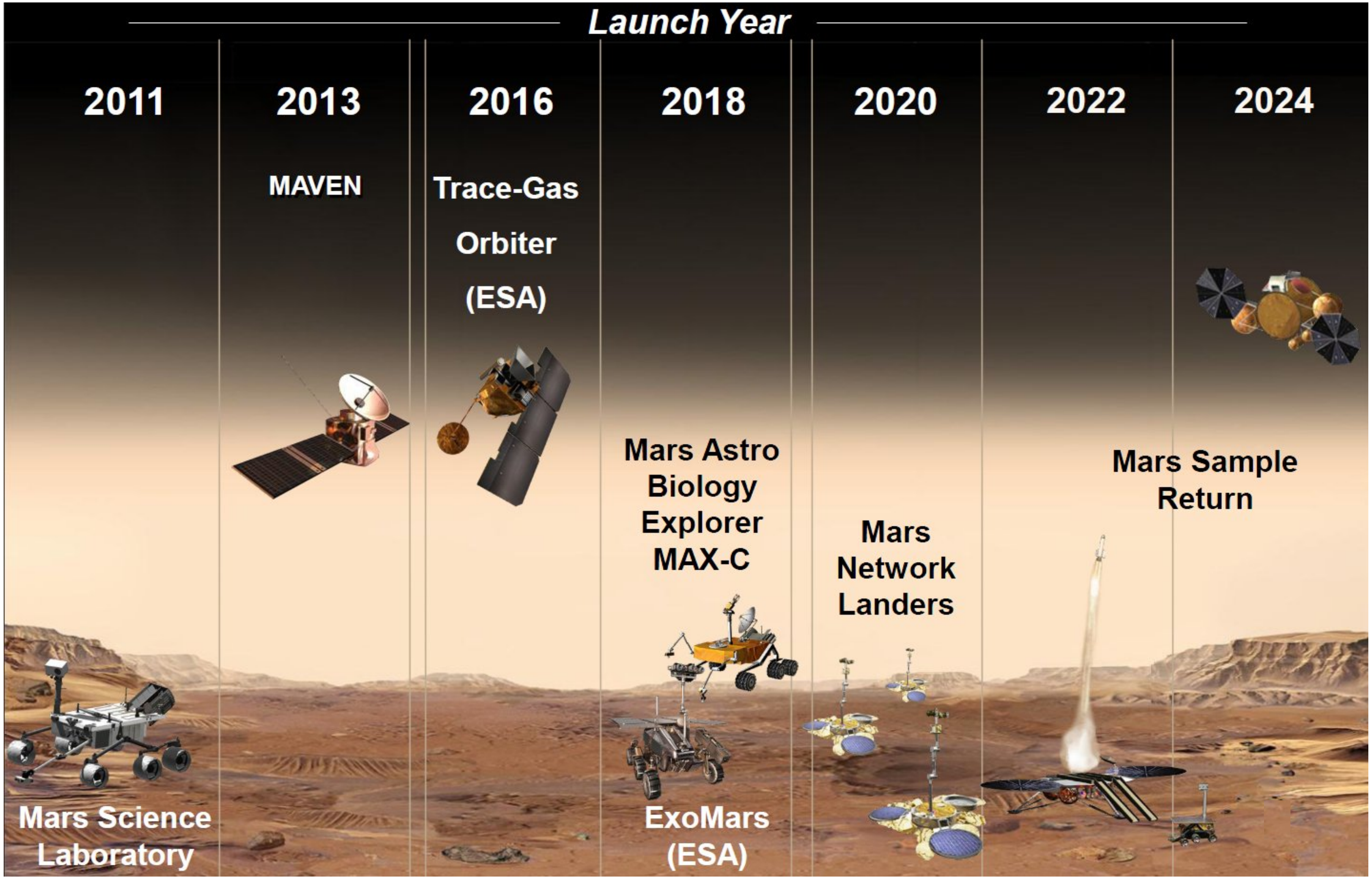
Sample Caching for Mars Sample Return

- **Why Mars?**
  - "Mars has crustal and atmospheric characteristics that make it a priority exploration target for understanding the origins of life"
  - "Essential energy, water, and nutrient requirements to support and sustain life are currently present and the Martian geologic record offers tantalizing clue of many ancient habitable environments"
  - "If life emerged and evolved on early Mars then it is possible, and indeed likely, that physical or chemical biosignatures are preserved in the exposed rock record"
- **Focus of Missions:**
  - Follow the Water (ODY, MER, MEX, MRO, PHX)
  - Habitable Environments (MSL, MAVEN, TGM, EXM)
  - Seek Signs of Life (MAX-C, MSR)
- **Motivation for Mars Samples:**
  - "Significantly increase our understanding of atmospheric, biologic, and geologic processes occurring there, as well as permit evaluation of the hazards to humans on the surface"
  - Scientific analysis could be done without the limited instrument payload and operational resources of the rover or lander
  - Samples could be distributed amongst international laboratories and the science community
  - Samples could be preserved for analysis with future instruments



Ref: Mars Astrobiology Explorer-Cacher (MAX-C): A Potential Rover Mission for 2018, Final Report of the Mars Mid-Range Rover Science Analysis Group, 2009.
MEPAG Next Decade Science Analysis Group, "Science Priorities for Mars Sample Return," *Astrobiology*, Vol. 8, No. 3, 2008.

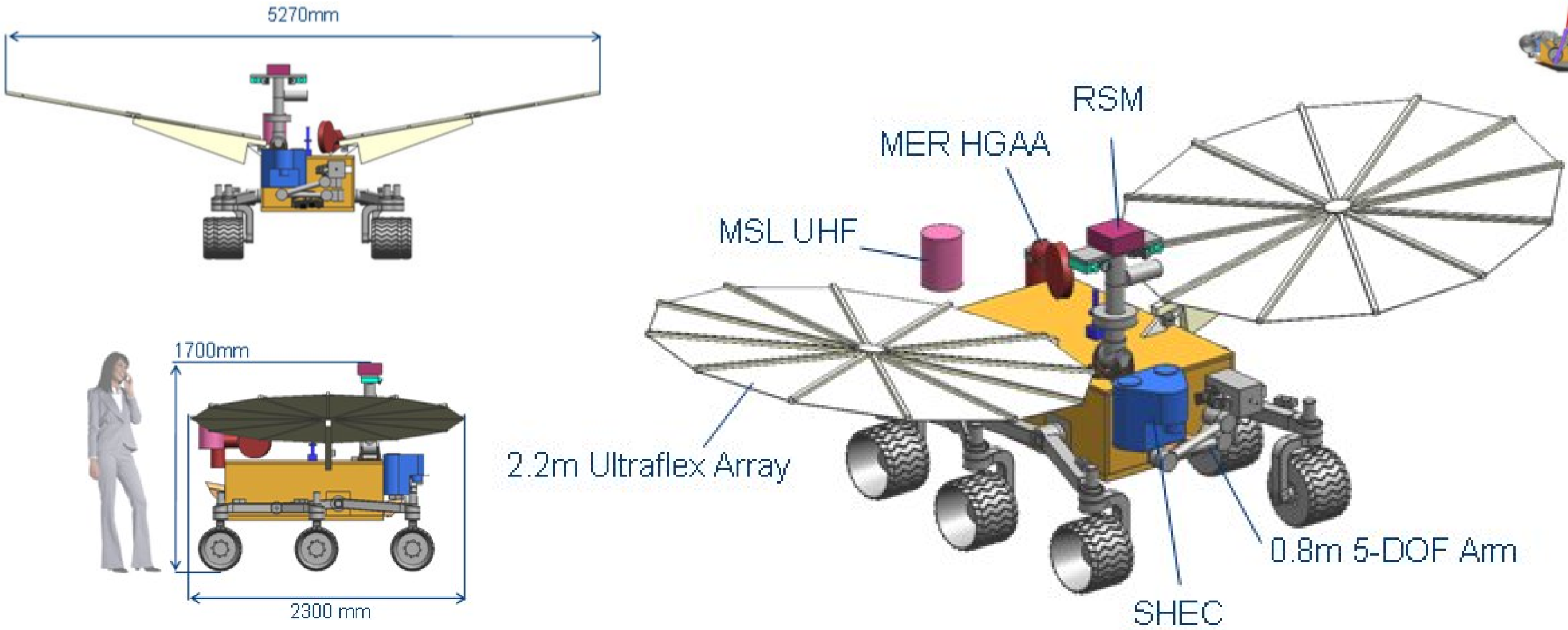
Potential Mars Mission Timeline



Ref: Kazz, G., NASA Mars Program, Future Mars Mission Plans/Scenarios, 2009.

Mars Astrobiology Explorer-Cacher (MAX-C)

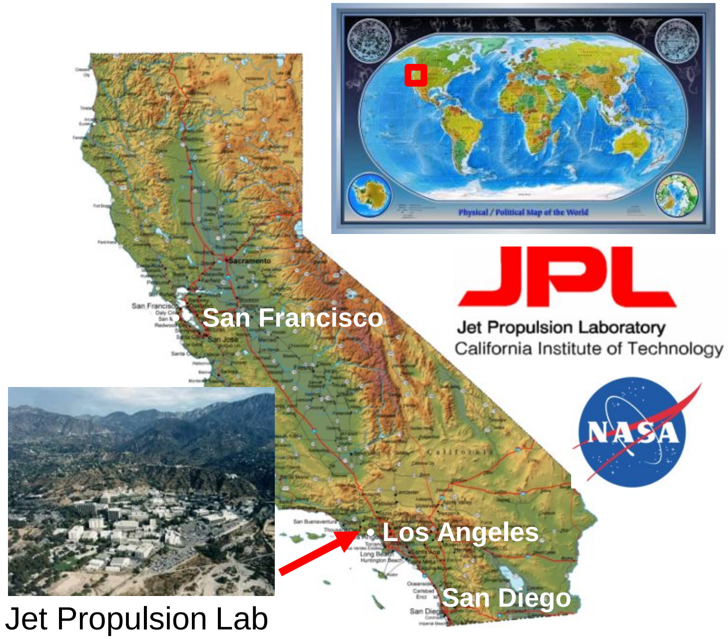
- **Proposed Mars Astrobiology Explorer-Cacher (MAX-C):**
  - Mid-size rover expected around 300 kg
  - Proposed for 2018 launch window alongside ESA's ExoMars rover using MSL-like EDL
  - Instruments for remote and contact science, as well as coring rocks
  - Baseline a sample caching subsystem for encapsulating rock cores for potential future return



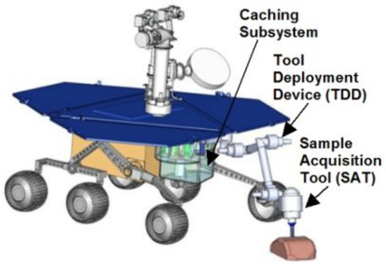
Ref: Salvo, C. and Elfving, A., "Proposed Mars Astrobiology Explorer – Cacher (MAX-C) & ExoMars 2018 (MXM-2018) Mission Formulation Status, *Jet Propulsion Laboratory, California Institute of Technology*, Presented at the 22nd MEPAG Meeting, Monroivia, CA, Mar. 17-18, 2010.

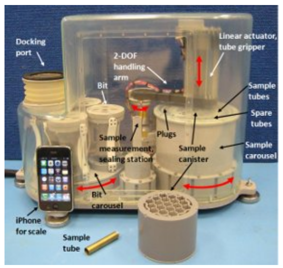
Integrated Mars Sample Acquisition & Handling (IMSAH)

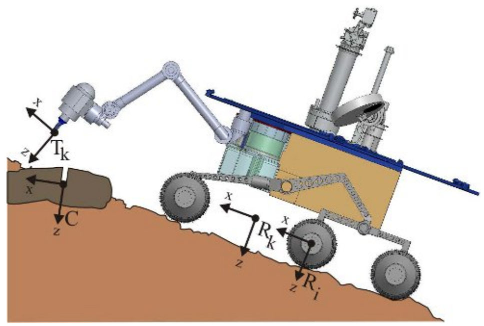
- **Integrated Mars Sample Acquisition & Handling (IMSAH) Task at JPL**
  - 3-year Jet Propulsion Laboratory RT&D task initiated in FY ‘09
  - **Objective:** Develop and validate to TRL 4 an integrated core and soil sample acquisition and caching system suitable for use on a 300kg MER-class Mars rover
  - **Target Mission:** 2018 MAX-C
  - Schedule:
    - FY ‘09: Trade space and concept development
    - FY ‘10: TRL 4 hardware development
    - FY ‘11: TRL 4 integrated validation on a rover



Jet Propulsion Lab
Pasadena, CA





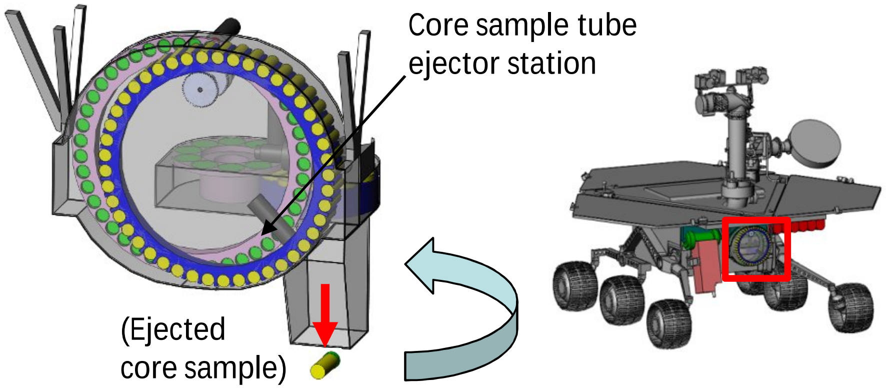


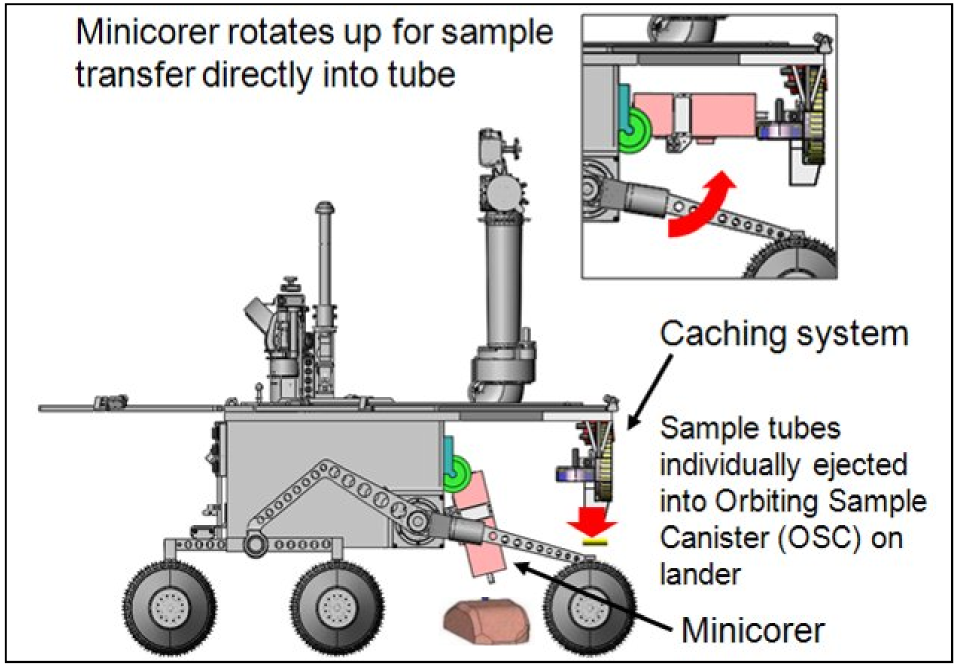
The subject matter in this paper is pre-decisional, and for discussion purposes only.

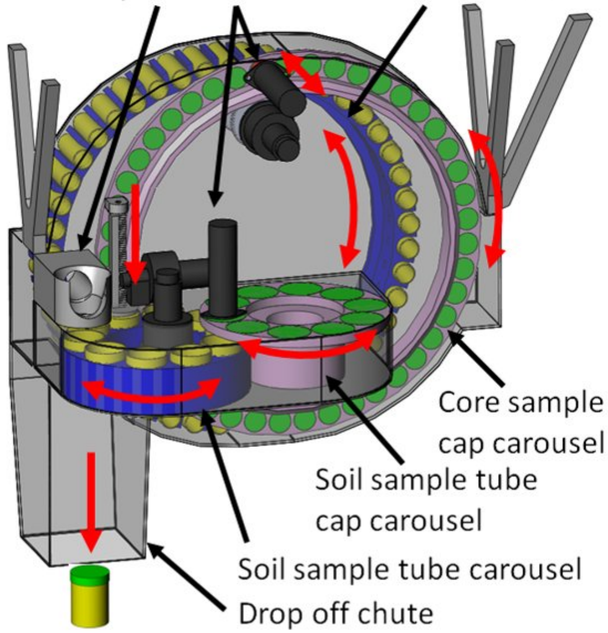
Previous Mars Caching Concepts

ATHENA Rover Caching Concept (1999)

- Proposed for MSR 03/05
- Rotary drag mini-corer capable of taking 50-60 cores of 8 mm wide by 25 mm in length
- Limited ability to compensate for rover slip
- Raw core ejection risk with broken cores
- Requires dropping off samples into OSC
- Not flown; rover evolved into MER



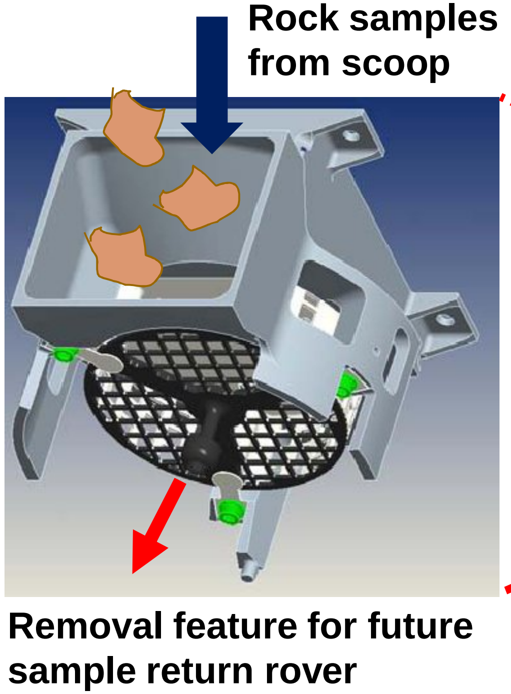


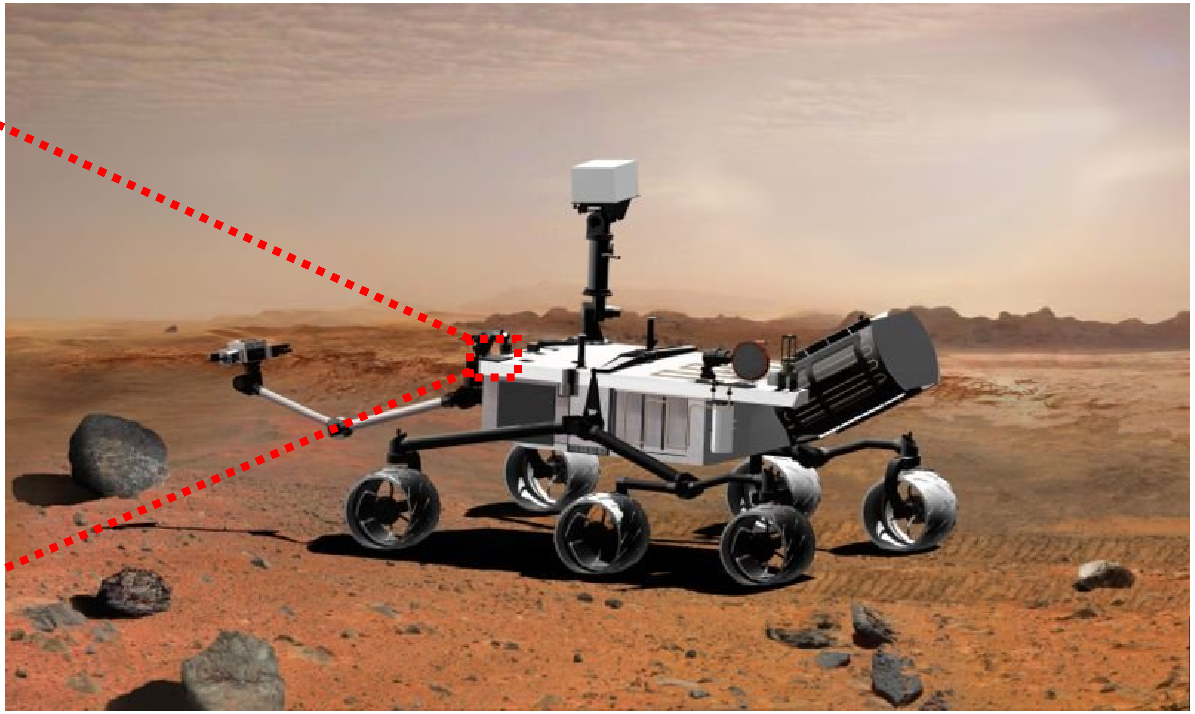


Previous Mars Caching Concepts

Mars Science Laboratory Caching Concept (2008)

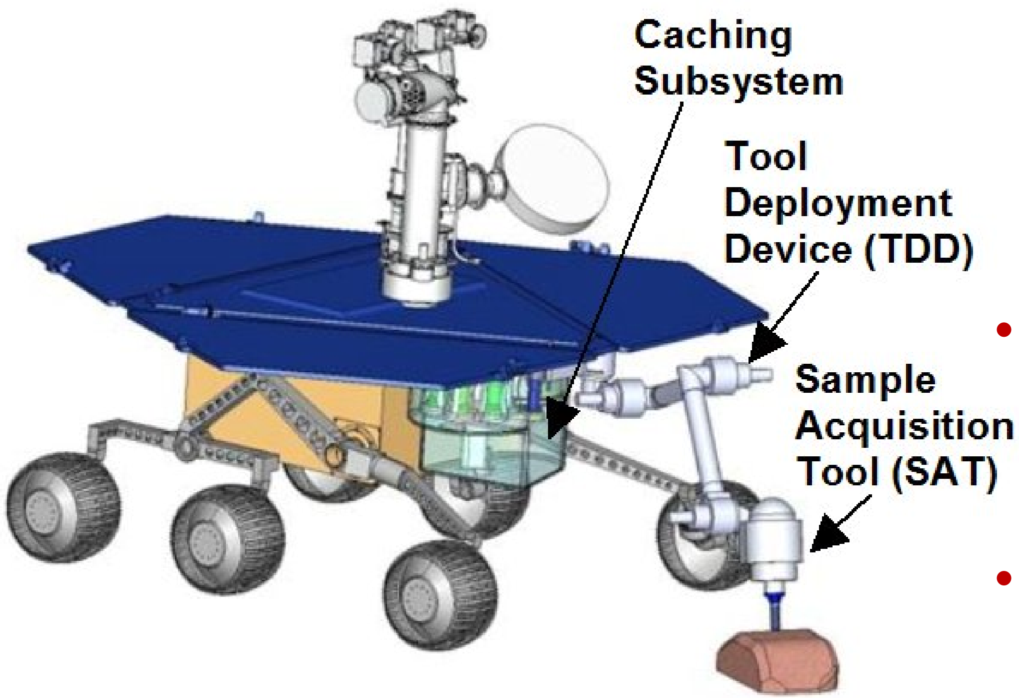
- Single cache container capable of accepting 5-10 rock samples 0.5-1.5 cm across
- Open to Mars environment
- Grasping feature for a manipulator on a future fetch rover to remove it from MSL
- Tabs holding container to the cradle bend away when the container is pulled out
- Not included in final configuration due to rover design issues and debated science value





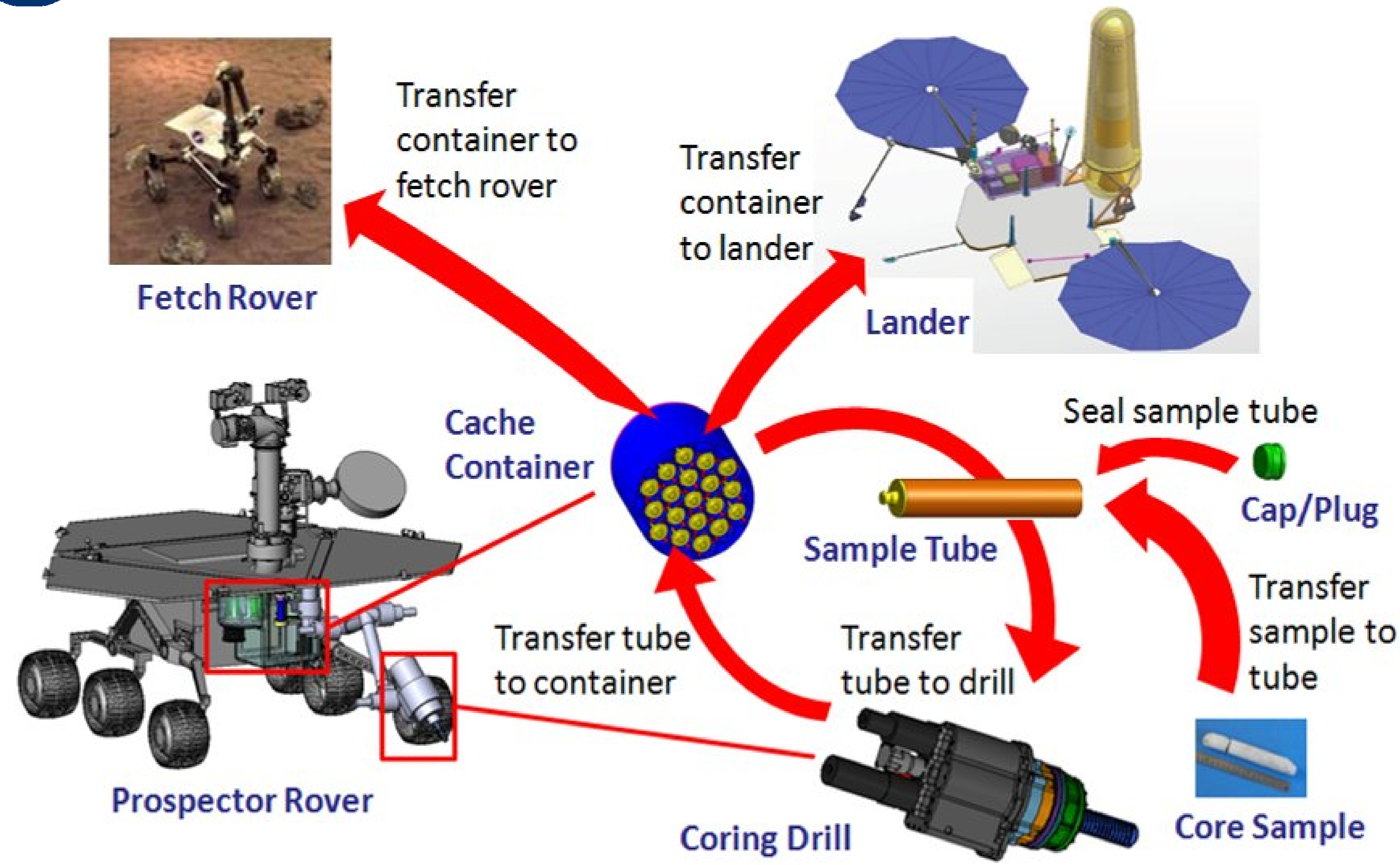
Ref: Karcz, J. S. et al., "The Implementation of the Mars Science Laboratory Sample Cache," *Ground Truth from Mars: Science Payoff from a Sample Return Mission*, Lunar Planetary Institute, Albuquerque, NM, Apr. 21-23, 2008.

JPL IMSAH Caching Concept



- **Caching Subsystem:**
  - **Sample Encapsulation:** Sample acquisition directly into the sample tube in the bit
  - **Sample Transfer**: Bit changeout for transferring sample to caching subsystem (sample in tube in bit)
  - **Functions**: Sample tube transfer in/out of bit, bit changeout, tube sealing, tube storage in canister
- **Tool Deployment Device:**
  - **Design:** 5 DOF arm
  - **Functions:** Tool deployment, alignment and linear feed; canister placement on the ground
- **Sample Acquisition Tool:**
  - **Technique:** Rotary percussion
  - **Functions:** Coring, breakoff, retention, bit changeout, linear spring for preload and vibration isolation

Sample Transfer Interactions



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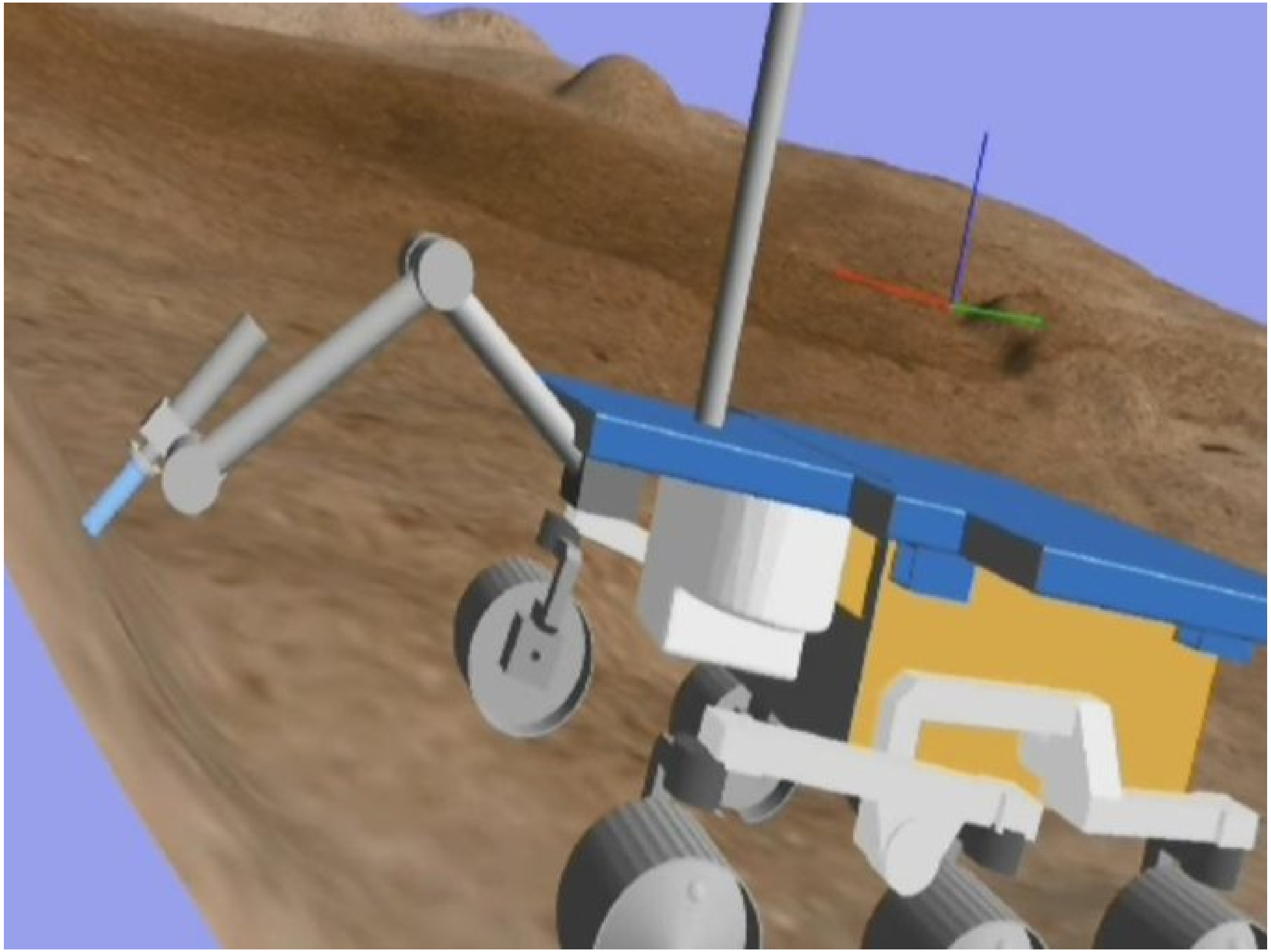
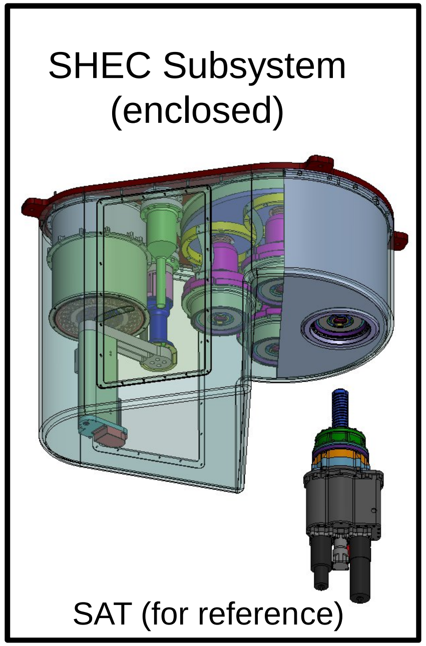
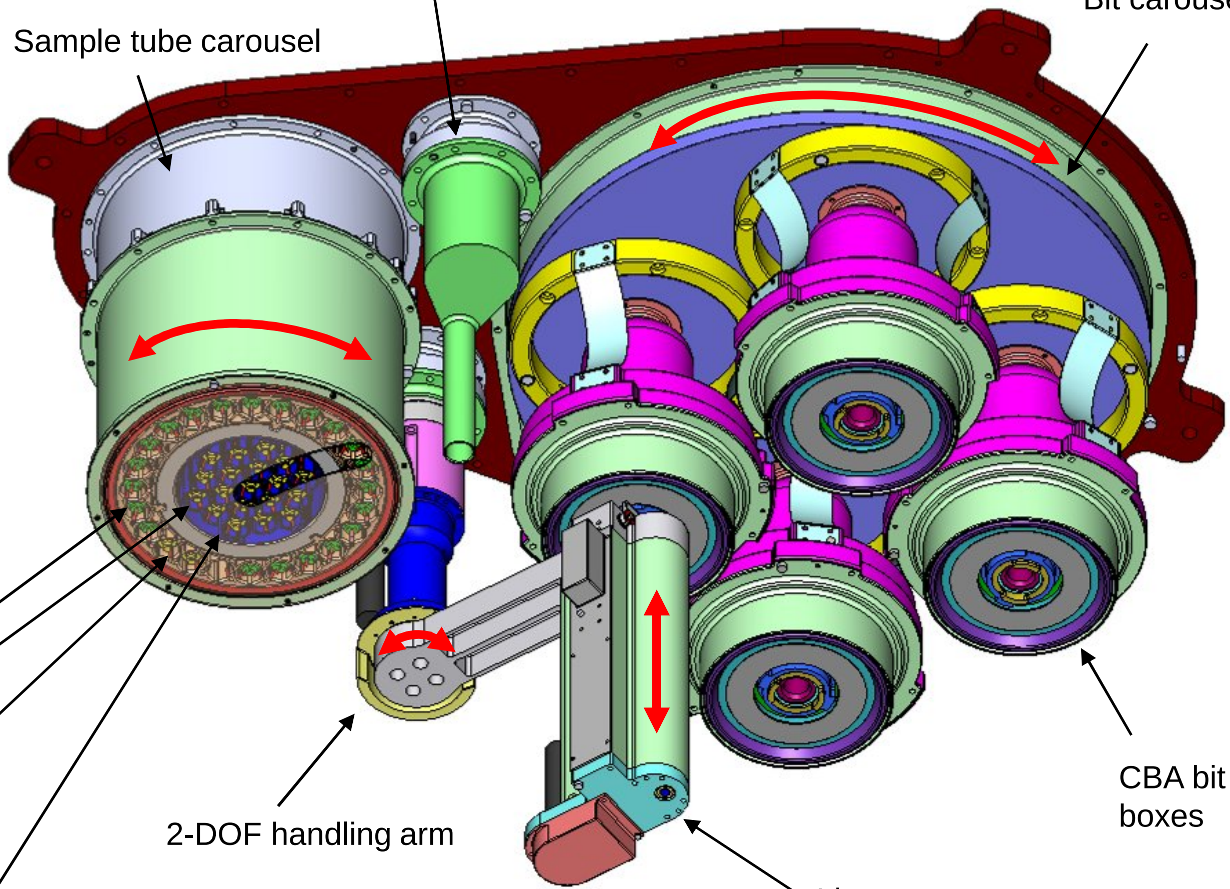
Movie, Operational Sequence



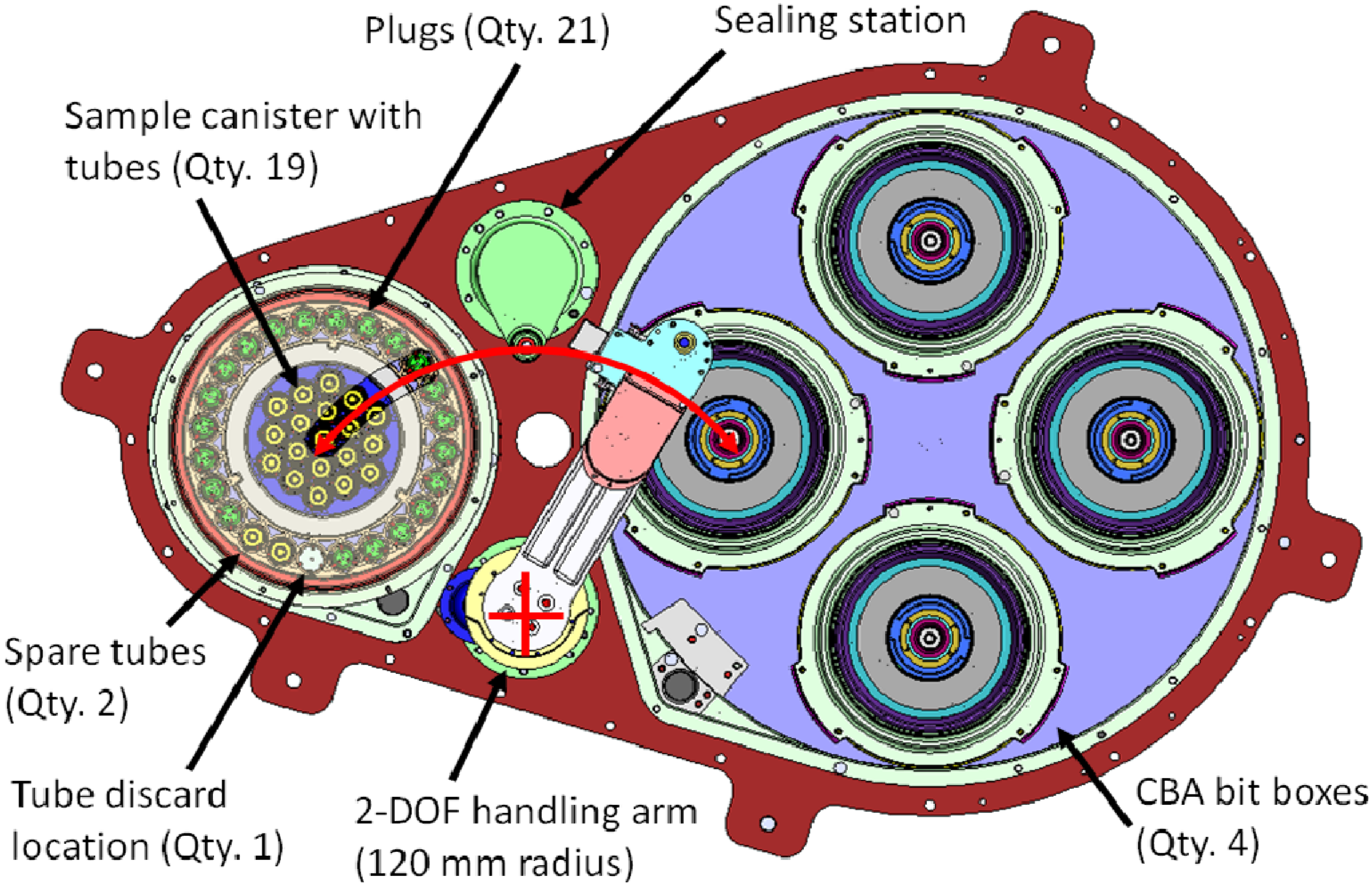
Video Link

Caching Subsystem –
Sample Handling, Encapsulation and Containerization Concept

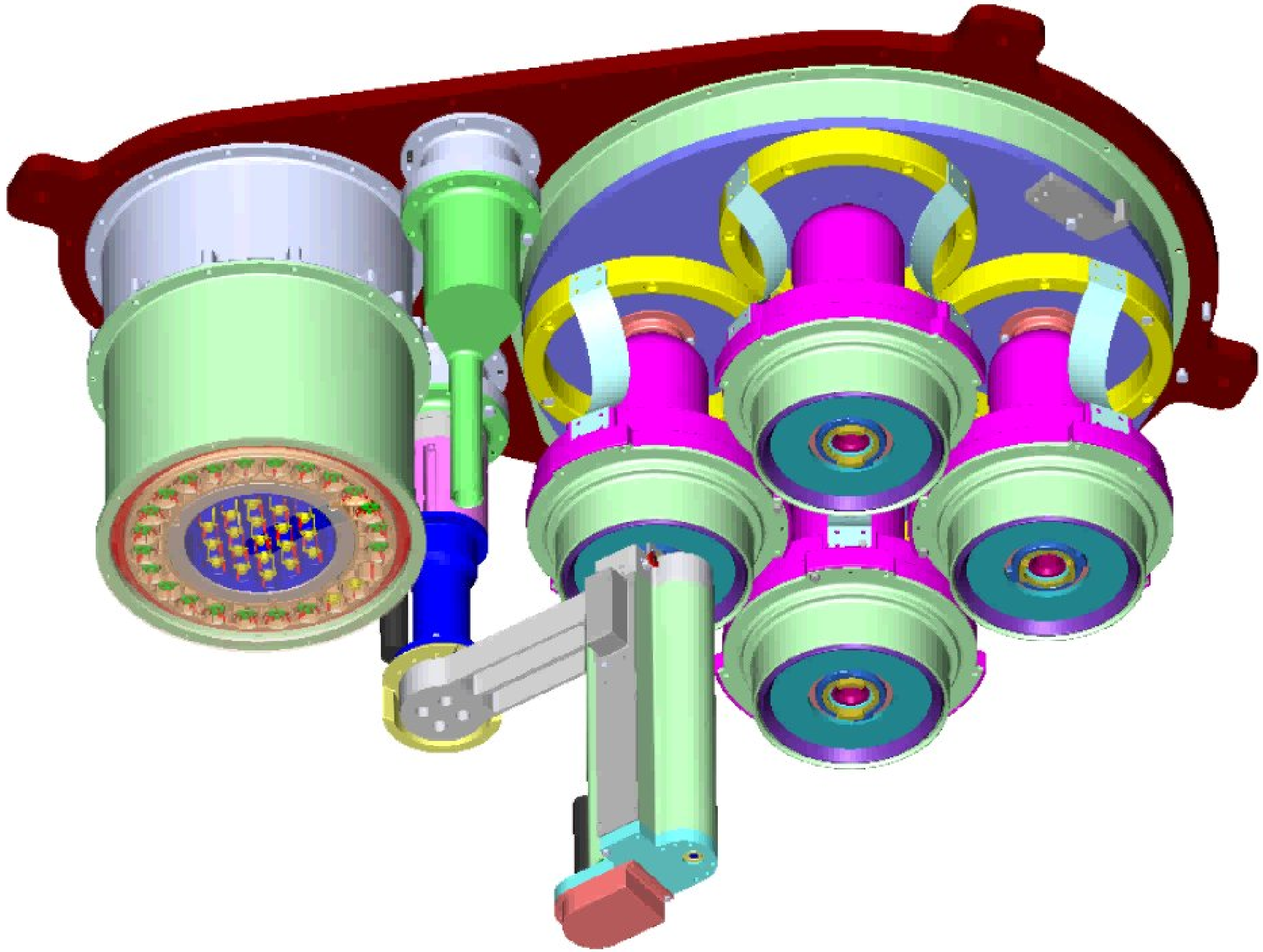




SHEC Handling Arm Stations



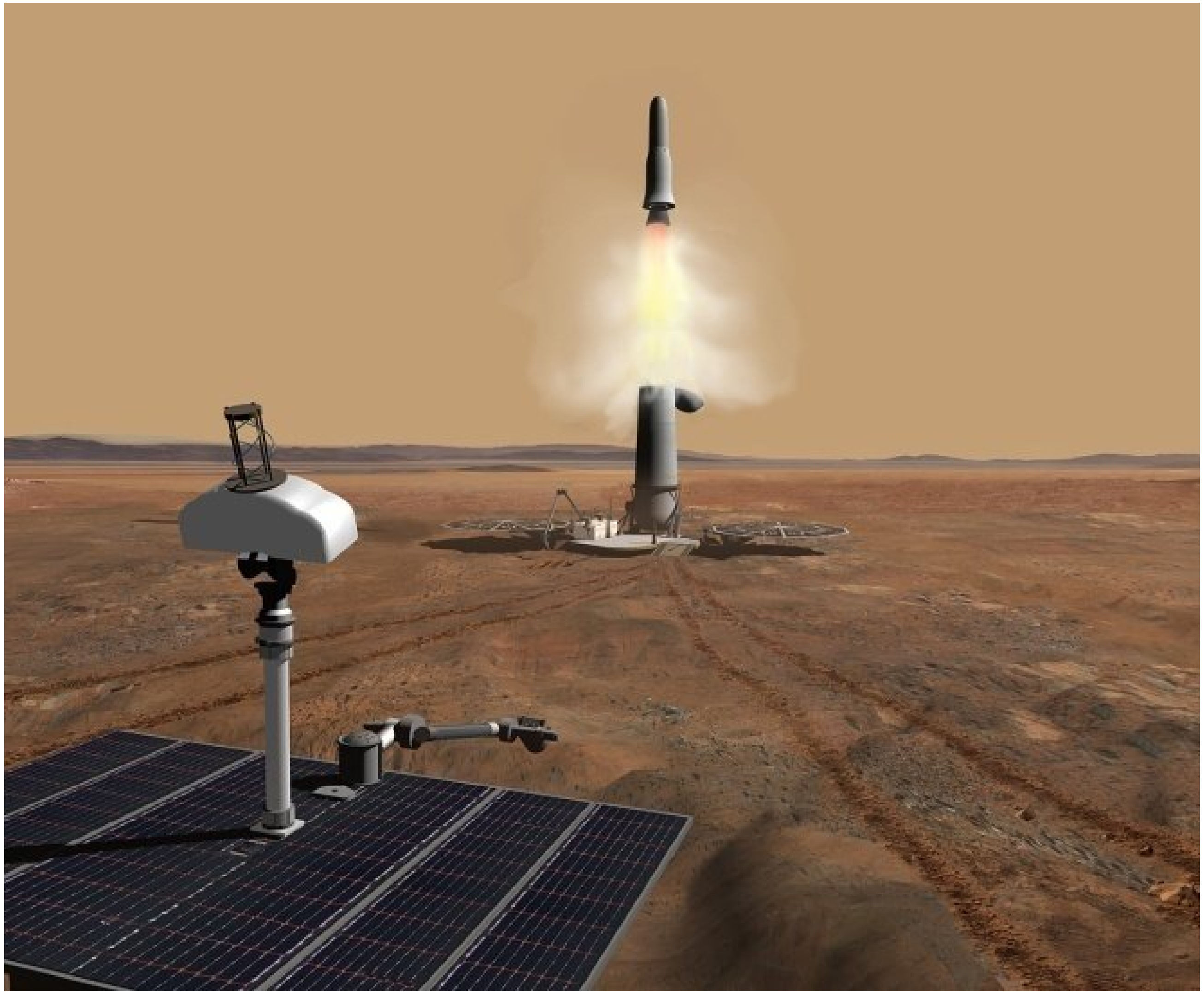
SHEC Animation



Video Link

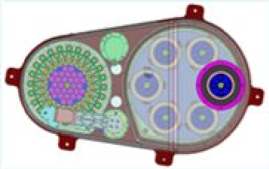
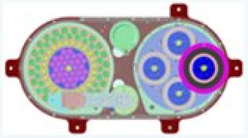
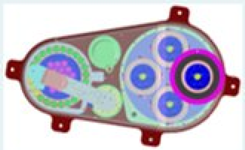
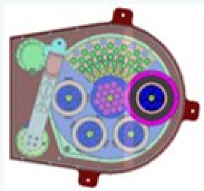
Quicktime Video

Bringing the Samples Back to Earth

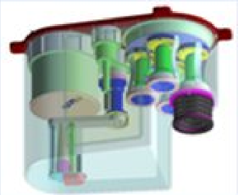
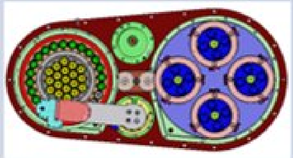
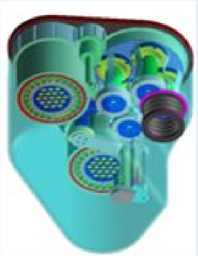
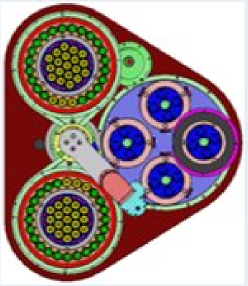
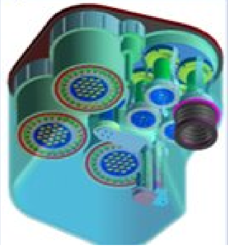
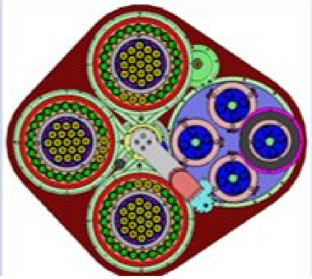


Credit: NASA JPL/Caltech

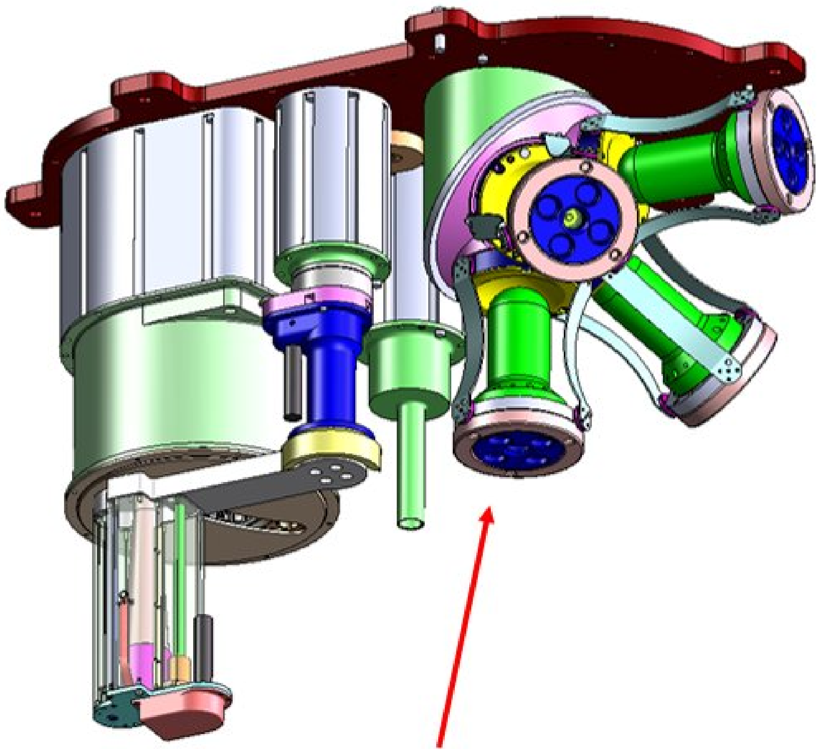
SHEC – Alternate Layouts

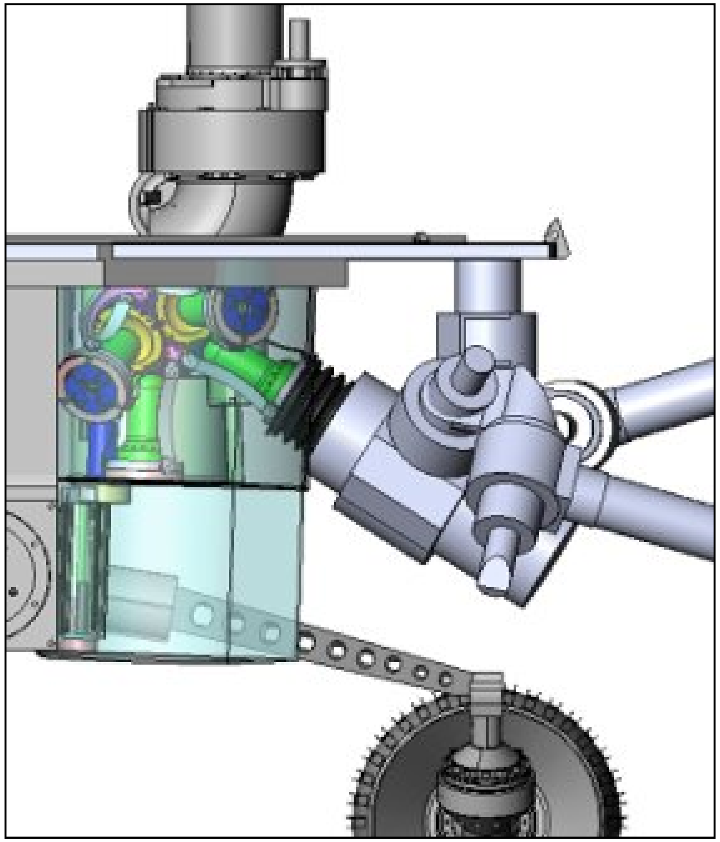
Configuration	Layout	Number of Bits	Number of Tubes	Comments
Full Version		6	31 sample tubes 31 plugs 24 spare tubes 17 spare plugs	Large sample storage, large bit storage, most room for drill interface
Reduced Bit Carousel		4	31 sample tubes 31 plugs 24 spare tubes 17 spare plugs	Large sample storage
Reduced Bit and Canister Carousel		4	19 sample tubes 19 plugs 2 spare tubes 2 spare plugs	Smallest footprint
Single-Combined Carousel		4	19 sample tubes 19 plugs 11 spare tubes 11 spare plugs	Requires 1 less actuator, least room for drill interface

SHEC – Multiple Canisters

Configuration	Layout	Number of Tubes
Single Canister 		19 sample tubes 19 plugs 2 spare tubes 2 spare plugs
Dual Canister 		38 sample tubes 38 plugs 4 spare tubes 4 spare plugs
Triple Canister 		57 sample tubes 57 plugs 6 spare tubes 6 spare plugs

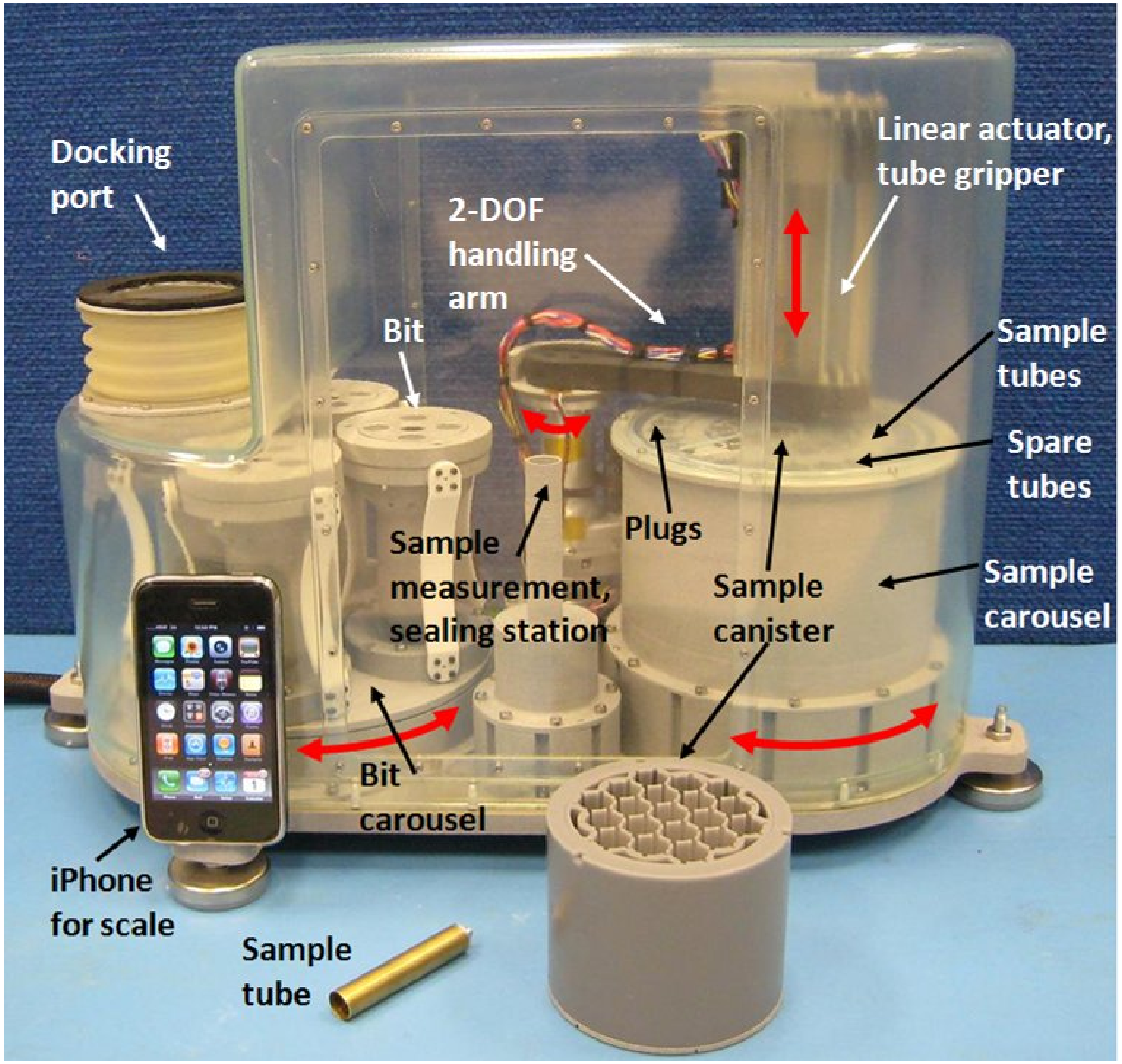
SHEC – Flexible Bit Interface



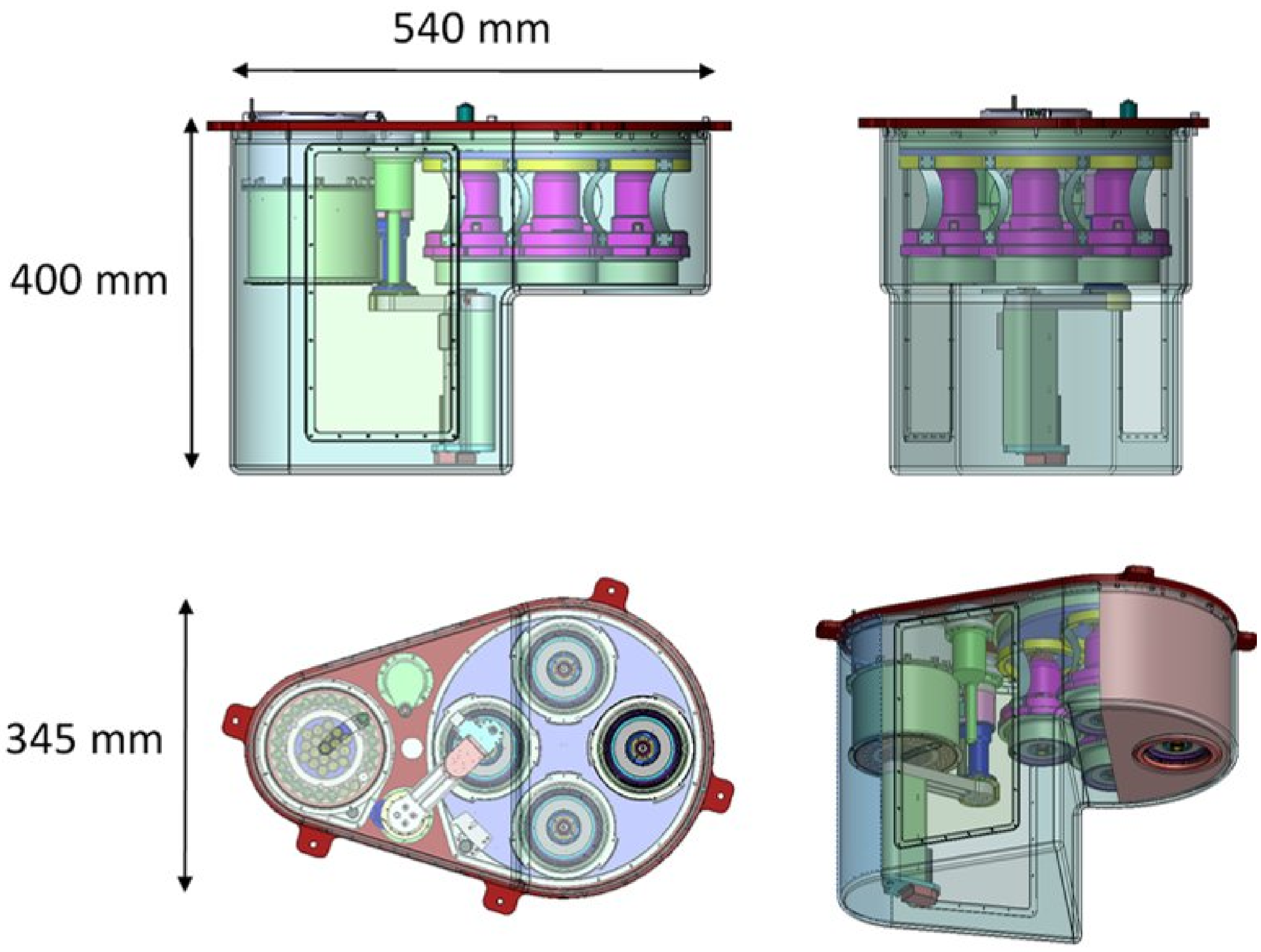


Angled bit carousel could allow variation in orientation of coring tool docking for bit changeout

SHEC Proof-of-Concept Prototype (2009)

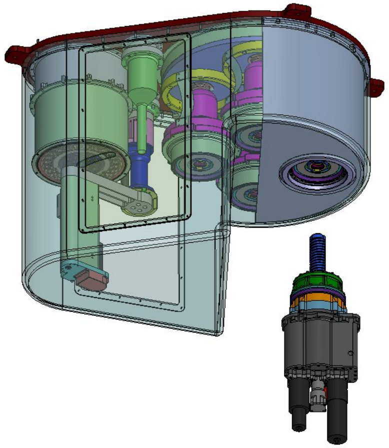


SHEC TRL 4 Prototype in Development (2010)



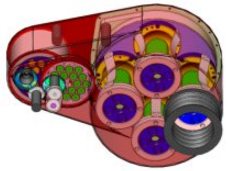
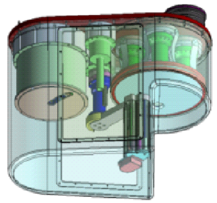
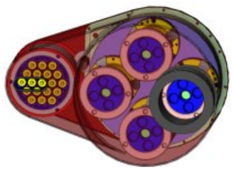
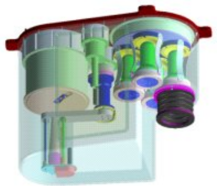
Conclusions

- A Sample Handling, Encapsulation, and Containerisation (SHEC) subsystem capable of sample caching functions for proposed future Mars sample caching missions such as MAX-C is being developed through the IMSAH task at the Jet Propulsion Laboratory.
- SHEC System Benefits:
  - Utilizes bit change-out to insert/remove sample tubes into bits
  - Collects samples directly into tube
    - Reduces contamination risks
    - Increases robustness to broken cores
  - Enables storage of tubes in a close-packed canister compatible with current Mars Sample Return architectures
  - Could lead to a simplified/lighter drill without the need for a push rod
- Flexibility in the design:
  - Expansion for samples tubes and bits
  - Additional sample canisters
  - Angle bit carousel
- Proof-of-concept prototype built and tested
- TRL 4 level design currently in development



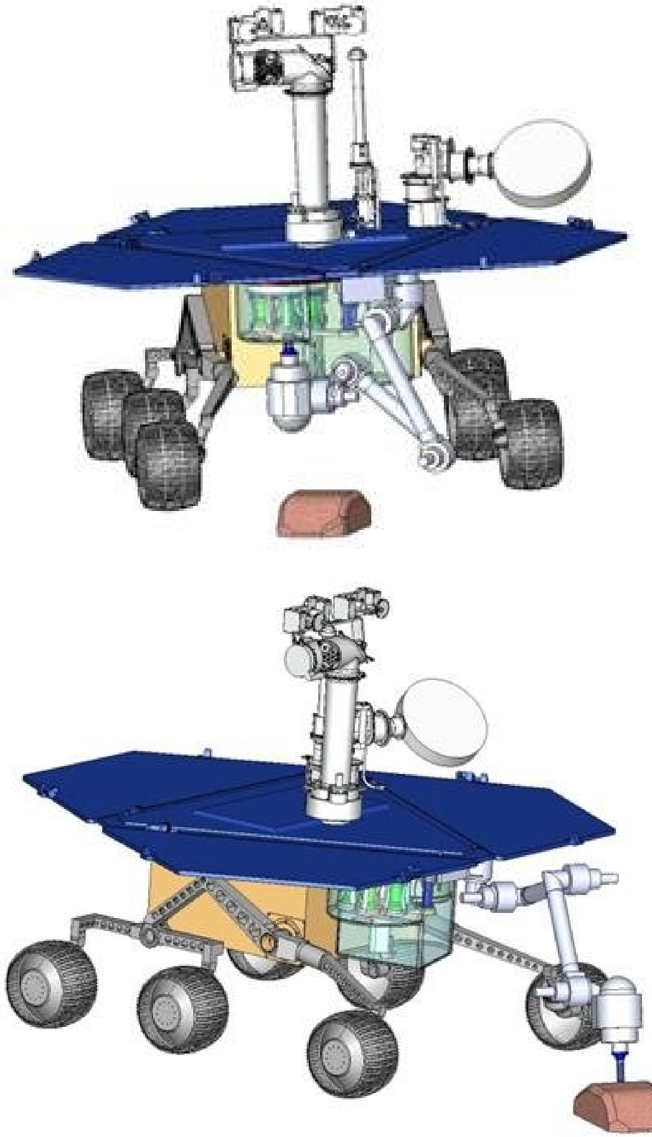
Backup Slides

Caching System Option Space

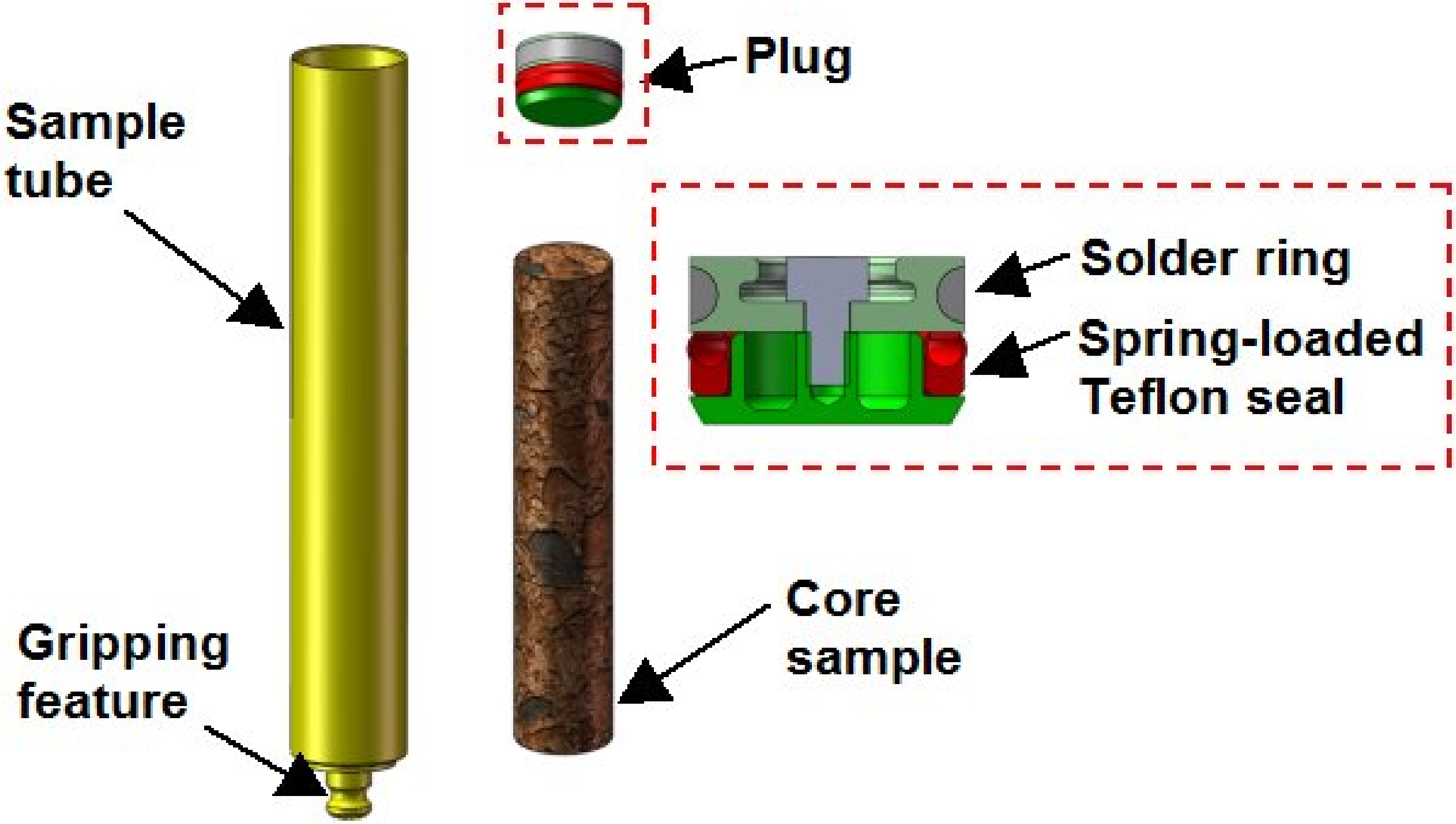
		Robustness to Broken Cores		Close Packing		Sample Contamination		Mass (consider system mass)	
Direct Core Transfer		Low, transfers raw core	↓	Transfer with large arm limits precision	↓	More exposed, increases risk	↓	Low mass, but drill needs a push rod	⇔
Indirect Core Transfer		Low, transfers raw core	↓	Transfer with small arm increases precision	↑	Less exposed, decreases risk	↑	Medium mass, but drill needs a push rod	↓
Direct Tube Transfer		High, transfers tube	↑	Transfer with large arm limits precision	↓	More exposed, increases risk	↓	Low mass, but drill needs a push rod and tube gripper	⇔
Indirect Tube Transfer		High, transfers tube	↑	Transfer with small arm increases precision	↑	Less exposed, decreases risk	↑	Medium mass, reduces drill functions (mass)	⇔

Sample Acquisition and Caching: Operational Sequence

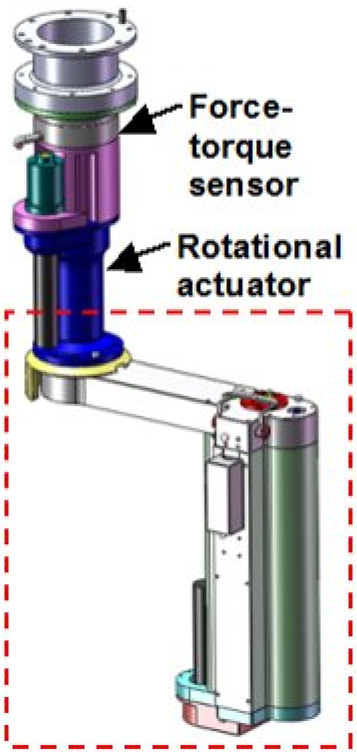
1. Sample Handling, Encapsulation and Containerization (SHEC) caching subsystem retrieves a new tube and puts it in a bit and rotates the bit to the bit port.
2. Tool Deployment Device (TDD) positions Sample Acquisition Tool (SAT) at SHEC bit port and SAT engages bit.
3. TDD deploys SAT to rock.
4. SAT acquires, breaks off, and retains a core directly into a sample tube in the bit.
5. TDD transports SAT to SHEC caching subsystem and inserts coring bit into SHEC bit port.
6. Bit is released by SAT and engaged by SHEC.
7. SHEC removes tube from bit, seals the tube, and stores the tube in the canister.
8. Ready to acquire another core sample.

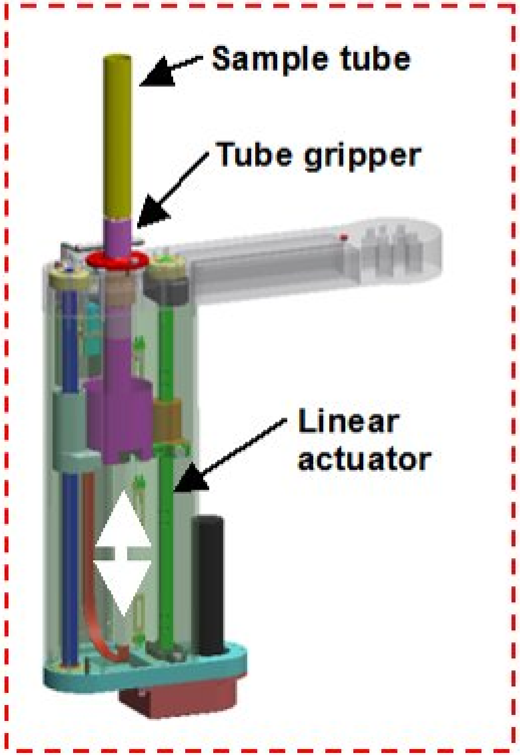


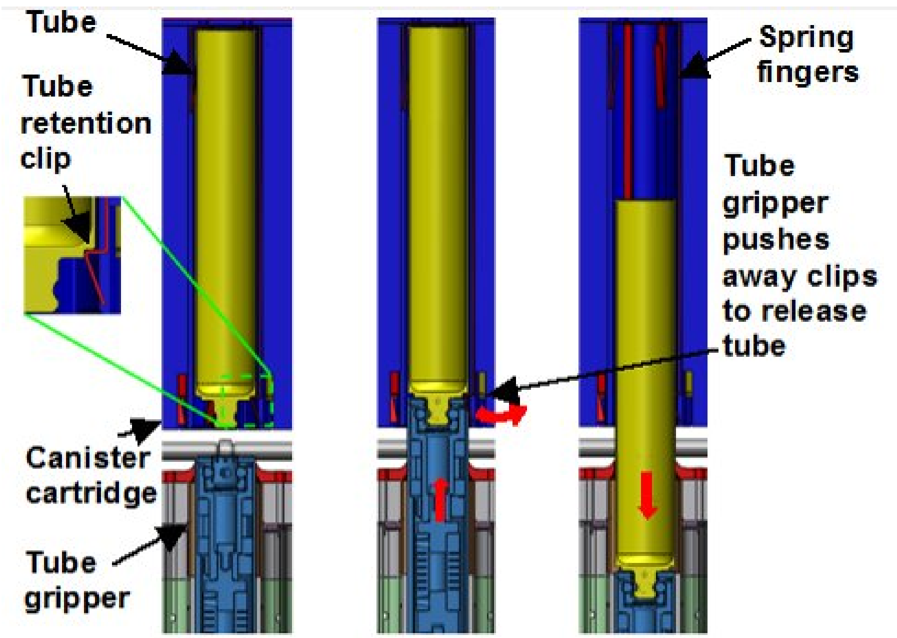
Sample Encapsulation



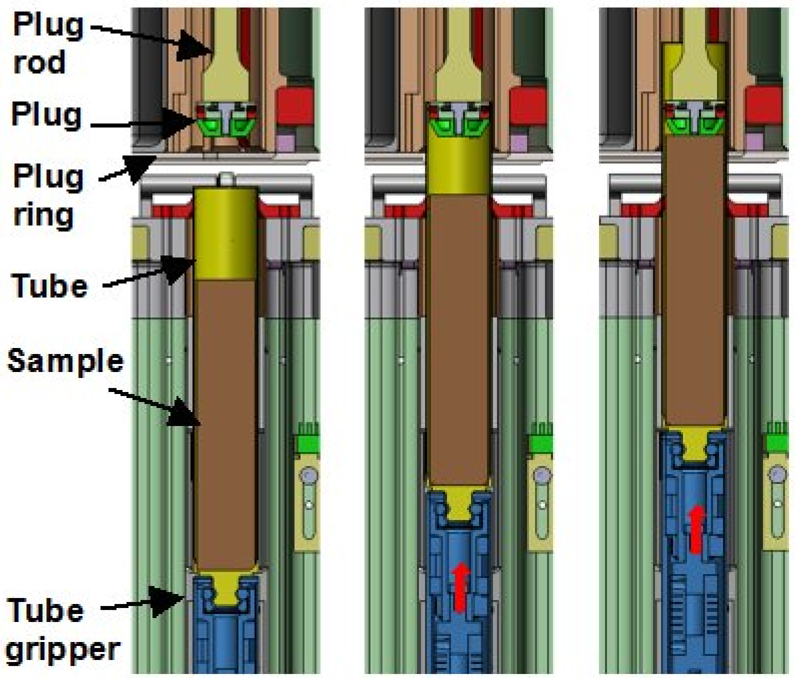
Sample Encapsulation

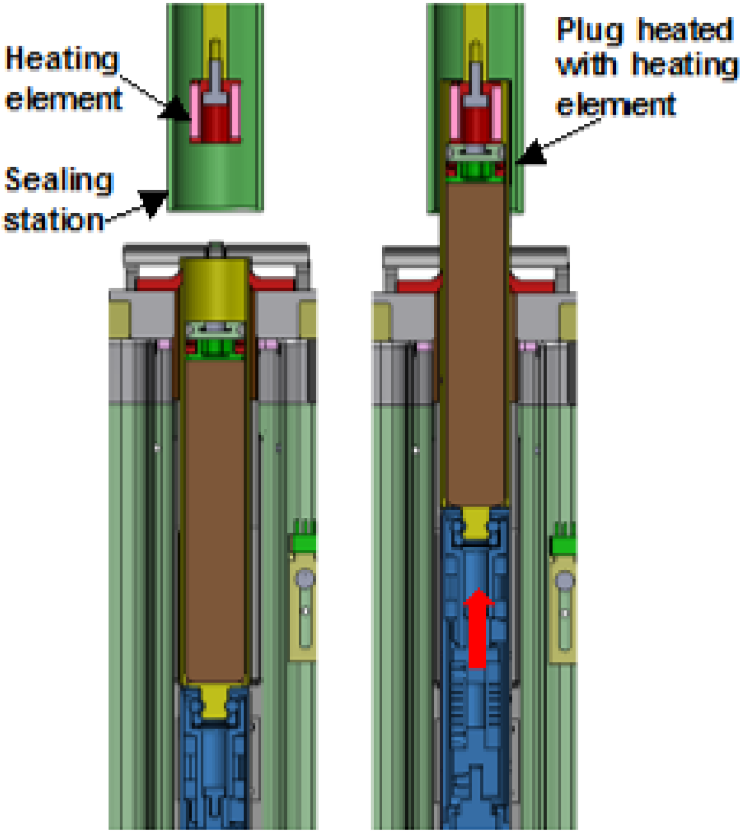




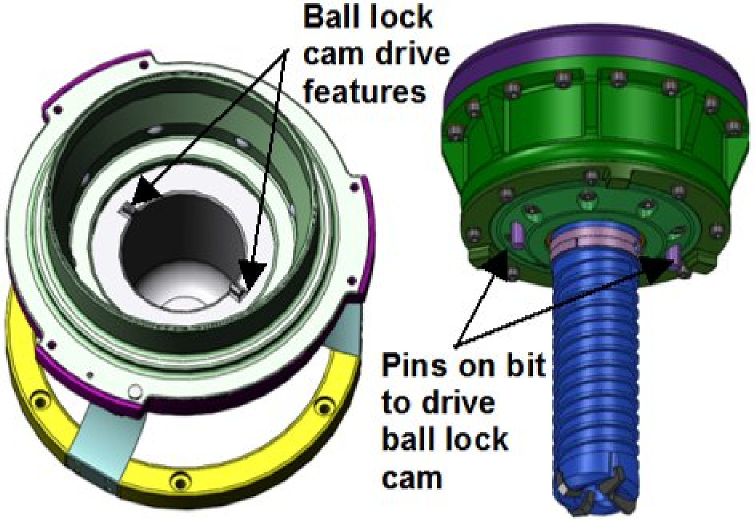


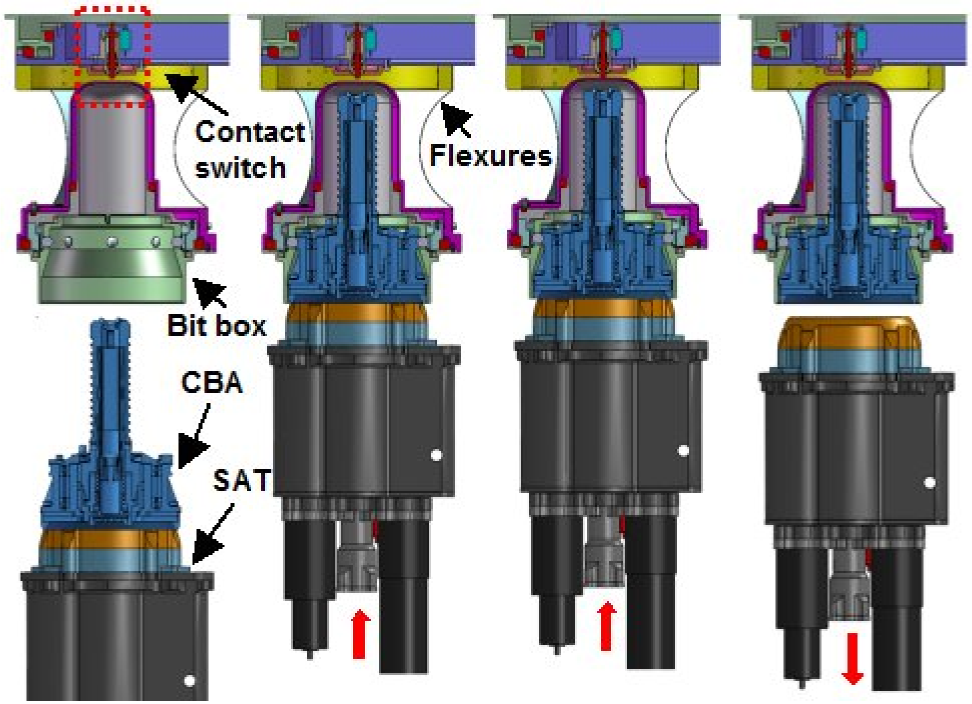
Sample Encapsulation



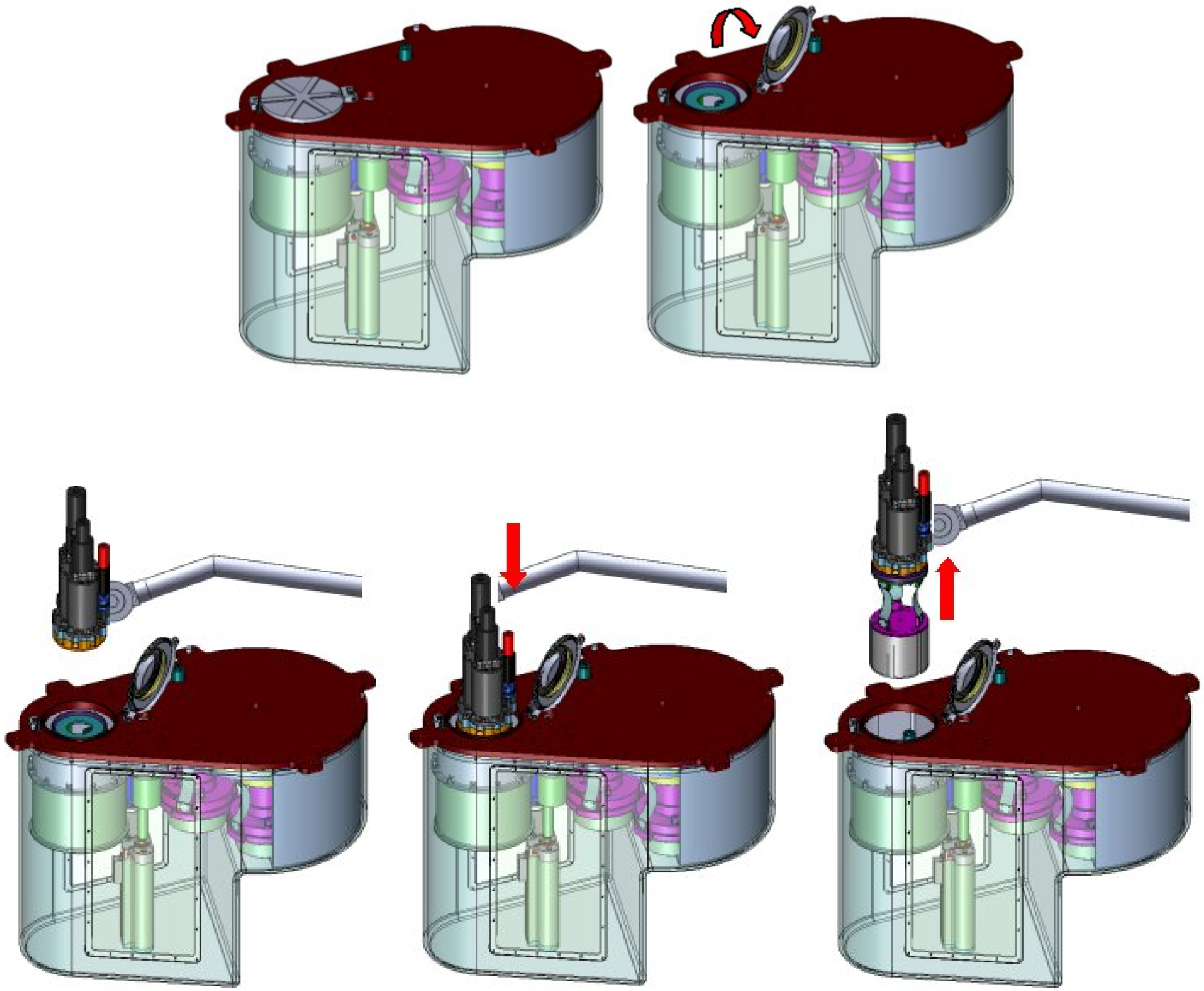


Bit Changeout

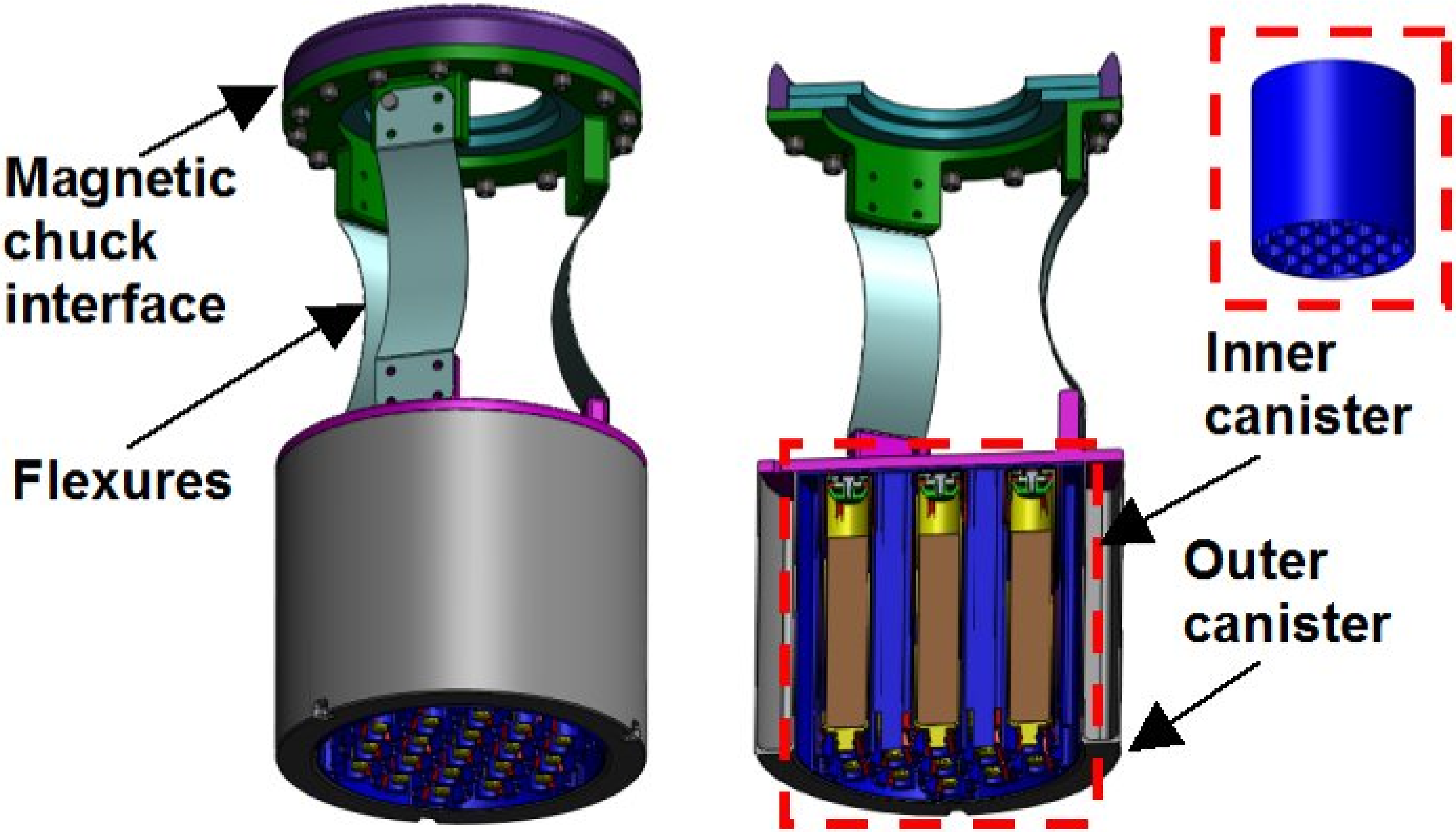




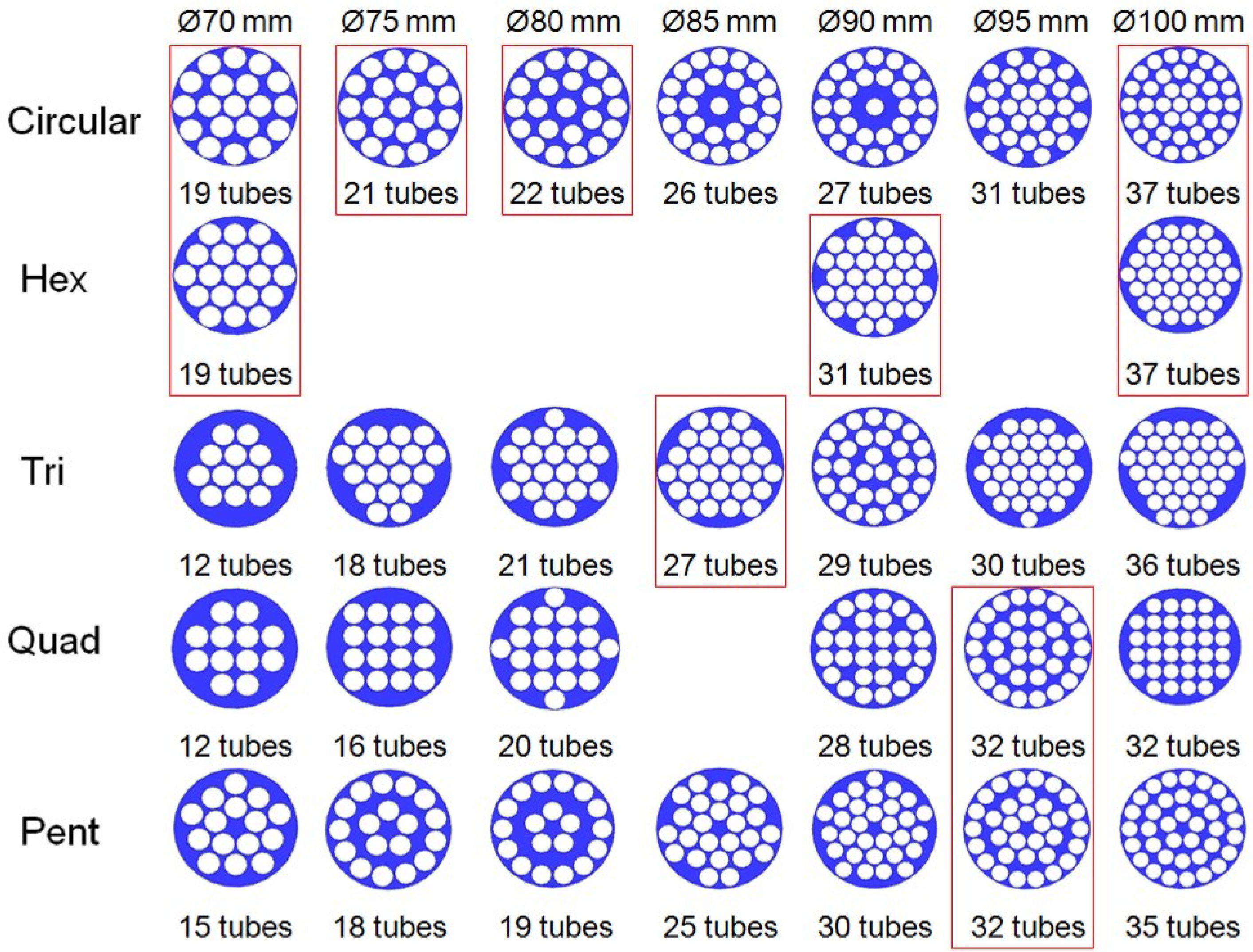
Canister Removal



Sample Canister



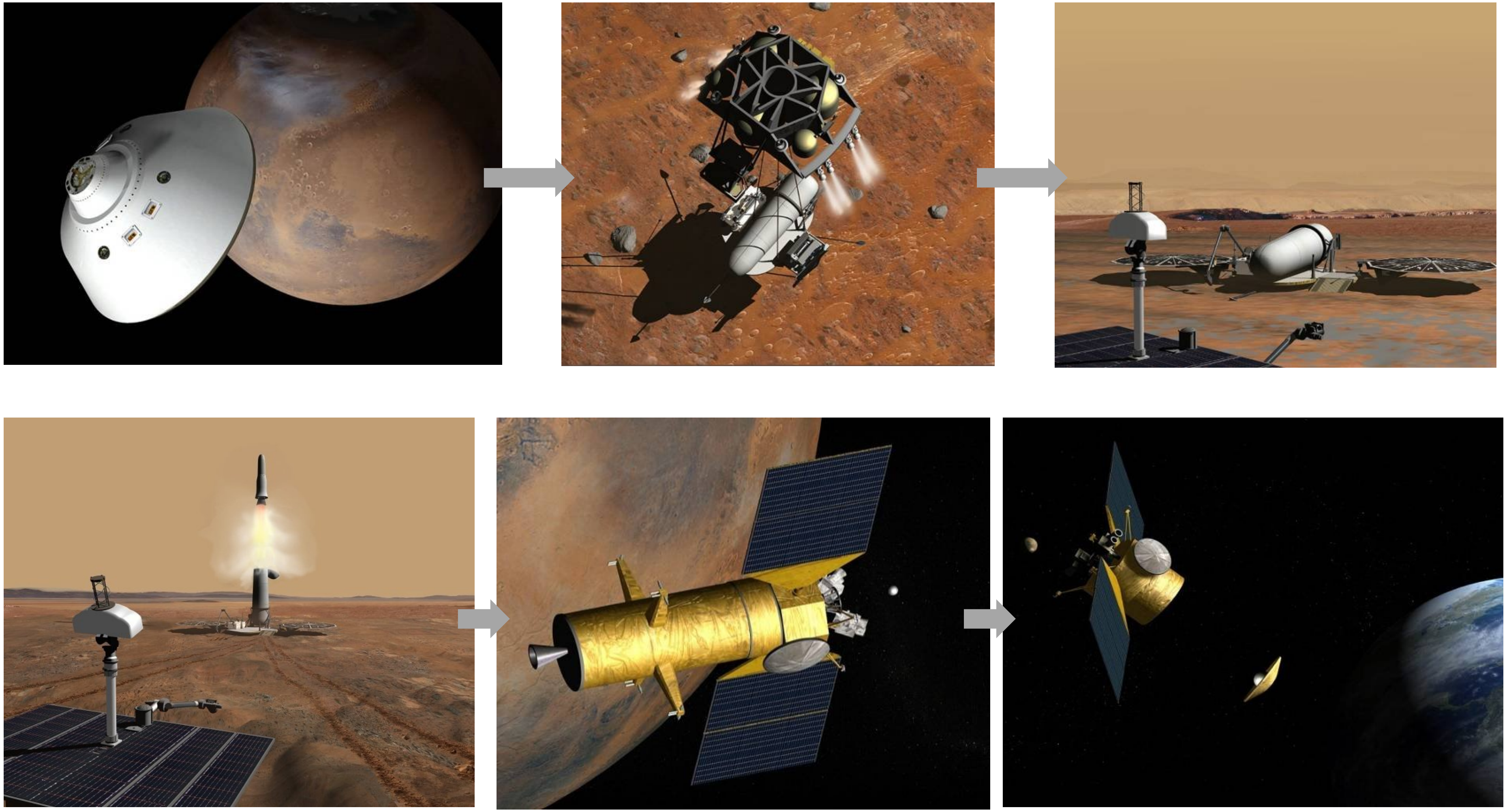
Canister Tube Configuration Options*



* Sample canister with 13 mm holes for 10 mm samples, with ~.75 mm min wall thickness between holes

Bringing the Samples Back to Earth

Possible Mars Sample Return Mission Storyboard



Credit: NASA JPL/Caltech